Claims

[c1]   1. A system for detecting and measuring concentrations of elements in fluids,
comprising:

an ionic preconcentration cell, comprising:

an upper high surface area electrode comprising a high specific surface area
thereof;

a lower high surface area electrode comprising a high specific surface area
thereof, substantially parallel to said upper high surface area electrode;

a central flow interelectrode gap separating said upper and lower high surface
area electrodes by a predetermined interelectrode gap width;

fluid flow means for flowing a fluid through said central flow interelectrode gap;
and

data associated with said cell enabling a concentration of at least one element
in said fluid to be deduced.

[c2]   2. The system of claim 1, further comprising:

voltage application means for applying a voltage differential between said upper
high surface area electrode and said lower high surface area electrode while
said fluid is flowing through said central flow interelectrode gap.

[c3]   3. The system of claim 2, further comprising:

a transportable voltage supply supplying said voltage differential.

[c4]   4. The system of claim 1, said ionic preconcentration cell further comprising:

an upper transmission window in intimate contact with an upper surface of said
upper high surface area electrode.

[c5]   5. The system of claim 4, said ionic preconcentration cell further comprising:

a lower transmission window in intimate contact with a lower surface of said
lower high surface area electrode.

[c6]   6. The system of claim 1, said ionic preconcentration cell further comprising:

inlet flow means for entering a fluid into said ionic preconcentration cell and
enabling said fluid to flow through said central flow interelectrode gap.

[c7]   7. The system of claim 6, said inlet flow means comprising at least one inlet

flow slot.

[c8]   8. The system of claim 6, said inlet flow means comprising a plurality of inlet
flow tubes.

[c9]   9. The system of claim 6, said inlet flow means comprising turbulence
enhancement means for enhancing a turbulence of the flow of said fluid.

[c10]   10. The system of claim 6, said inlet flow means comprising debris cleaning
means for cleaning debris from said inlet flow means.

[c11]   11. The system of claim 1, said ionic preconcentration cell further comprising:
outlet flow means for exiting said fluid out from said ionic preconcentration cell
after said fluid has flowed through said central flow interelectrode gap.

[c12]   12. The system of claim 11, said outlet flow means comprising at least one
outlet flow slot.

[c13]   13. The system of claim 11, said outlet flow means comprising a plurality of
outlet flow tubes.

[c14]   14. The system of claim 11, said outlet flow means comprising debris cleaning
means for cleaning debris from said outlet flow means.

[c15]   15. The system of claim 1, said ionic preconcentration cell further comprising:
a cell collector body in turn comprising a material comprising:
substantially no conductivity;
resistance to ionic leaching; and
resistance to radiation degradation from x-rays to which said preconcentration
cell is to be exposed.

[c16]   16. The system of claim 1, said ionic preconcentration cell further comprising:
a cell collector body comprising a material selected from the material group
consisting of: plastic, glass, and fiberglass.

[c17]   17. The system of claim 1, said ionic preconcentration cell further comprising:
a cell collector body comprising Delrin ® plastic.

[c18]   18. The system of claim 1:

said upper high surface area electrode further comprising an upper electrode

thickness less than or equal to approximately $\lambda = 1 / \mu * \rho$, wherein:

λ is an optical depth in said fluid of a characteristic photonic energy from an

element of interest for which a fluidic concentration is to be measured by said

system;

μ is a mass absorption coefficient of said upper high surface area electrode; and

ρ is a material density of said upper high surface area electrode.

[c19]   19. The system of claim 18:

said lower high surface area electrode further comprising an upper electrode

thickness less than or equal to approximately $\lambda = 1 / \mu * \rho$, wherein:

λ is an optical depth in said fluid of a characteristic photonic energy from an

element of interest for which a fluidic concentration is to be measured by said

system;

μ is a mass absorption coefficient of said lower high surface area electrode; and

ρ is a material density of said lower high surface area electrode.

[c20]   20. The system of claim 1, said upper high surface area electrode and said

lower high surface area electrode further comprising an ordinary surface area

approximately equal to an interrogation spot area of x-rays to which said

preconcentration cell is to be exposed.

[c21]   21. The system of claim 4, said upper transmission window comprising a

surface area approximately equal to an interrogation spot area of x-rays to

which said preconcentration cell is to be exposed.

[c22]

The system of claim 2, said central flow interelectrode gap comprising said

predetermined interelectrode gap width, designated d, within a interelectrode

gap range specified by:

$$d = \frac{\sigma}{q\varepsilon}\frac{\Phi}{w_f}\frac{w_i}{n_f}\frac{A}{C F}\times100\% \approx 2\times10^{-9}\frac{\Phi w_i A}{q\varepsilon w_f n_f F}\times100\% \propto \frac{\Phi A}{\varepsilon F}$$

, wherein:

ε designates a predetermined percentage of at least one element of interest to

be extracted from said fluid, σ designates a composite conductivity of said

fluid, Φ designates a potential applied by said voltage application means across said electrodes, $q = 1.60 \times 10^{-19}$ Coulomb designates the unit charge, A designates an ordinary surface area covered by said electrodes, n_f designates a number density of said fluid, w_i and w_f designate atomic / molecular weights, respectively, of at least one element of interest and of said fluid, C designates a concentration of said at least one element of interest in said fluid, and F designates a flow rate of said fluid through said ionic preconcentration cell;

said high surface area electrodes further comprise said ordinary surface area A approximately equal to an interrogation spot area of x-rays to which said preconcentration cell is to be exposed;

said ϵ is chosen to be below approximately 5% for said at least one element of interest;

said Φ is chosen to be below an electrochemical potential of said at least one element of interest and below an electrolysis potential of said fluid;

said F is chosen to exert no more than approximately .1 atm of pressure upon an upper transmission window of said ionic preconcentration cell in intimate contact with an upper surface of said upper high surface area electrode;

said n_f and said w_f are chosen with reference to said at least one element of interest; and

said w_i is chosen with reference to said fluid.

[c23]   23. The system of claim 1, said central flow interelectrode gap comprising said predetermined interelectrode gap width, designated d, with:

a minimum gap width selected from the minimum gap width group consisting of 2 mm, 1 mm, .5 mm, and .25 mm; and

a maximum gap width selected from the maximum gap width group consisting of 2 mm, 5 mm and 10 mm.

[c24]   24. The system of claim 4, said upper transmission window comprising:

an atomic number below 10;

structural rigidity to support up to 1/10 atm. of pressure without bowing more than approximately 100 microns;

substantial impermeability relative to said fluid;

x-ray transparency greater than 90% for characteristic photon energies from an

element of interest for which a fluidic concentration is to be measured by said system;

x-ray scattering therefrom minimized to less than approximately 10% of radiation scattered from a column of said fluid equal to one optical depth in said fluid of a characteristic photonic energy from an element of interest for which a fluidic concentration is to be measured by said system; and

freedom from any single contaminant in excess of 1 part per million, when measured by x-ray fluorescence.

[c25]   25. The system of claim 5, said lower transmission window comprising:
an atomic number below 10;
structural rigidity to support up to 1/10 atm. of pressure without bowing more than approximately 100 microns;
substantial impermeability relative to said fluid;
x-ray transparency greater than 90% for characteristic photon energies from an element of interest for which a fluidic concentration is to be measured by said system;
x-ray scattering therefrom minimized to less than approximately 10% of radiation scattered from a column of said fluid equal to one optical depth in said fluid of a characteristic photonic energy from an element of interest for which a fluidic concentration is to be measured by said system; and
freedom from any single contaminant in excess of 1 part per million, when .measured by x-ray fluorescence.

[c26]   26. The system of claim 4, said upper transmission window comprising Kapton ® .

[c27]   27. The system of claim 5, said lower transmission window comprising Kapton ® .

[c28]   28. The system of claim 1:
said upper high surface area electrode and said lower high surface area electrode comprising a high surface area material in turn comprising:
a large plurality of pores characterized by a specific surface area of at least approximately 100 m^3/g;

an average pore diameter of said pores between approximately 30 nm and 10 nm per pore;

a distribution of said pore diameters grouped with a standard deviation of less than approximately 10nm around said average pore diameter;

an x-ray transparency greater than approximately 90% for characteristic photon energies from an element of interest for which a fluidic concentration is to be measured by said system;

electrical conductivity of 10-40 mOhms-cm when fabricated into a ¼ mm thick electrode;

the ability to contain approximately at least 0.1% by weight of foreign material relative to said high surface area material prior to saturation;

high structural rigidity wherein a displacement under the flow of said fluid does not exceed approximately 0.25mm;

high wetting ability wherein an approximately ¼ mm thick sheet of said high surface area material becomes substantially wetted in less than approximately three seconds; and

freedom from metallic impurities in excess of approximately .5 parts per million, when measured by XRF analysis.

[c29]   29. The system of claim 28, said large plurality of pores characterized by a specific surface area of at least approximately 400 m^3/g.

[c30]   30. The system of claim 28, said large plurality of pores characterized by a specific surface area of at most approximately 1000 m^3/g.

[c31]   31. The system of claim 29, said large plurality of pores characterized by a specific surface area of at most approximately 1000 m^3/g.

[c32]   32. The system of claim 1, said upper high surface area electrode and said lower high surface area electrode each comprising nano-cellular carbon.

[c33]   33. The system of claim 1, said upper high surface area electrode and said lower high surface area electrode each comprising a carbon aerogel.

[c34]   34. The system of claim 1, said upper high surface area electrode comprising a thickness less than approximately $\lambda = 1/\mu\rho$; wherein:

λ designates an optical depth of said upper high surface area electrode when wetted with said fluid;

μ designates a mass absorption coefficient of said high surface area electrode when wetted with said fluid; and

ρ designates a density of said high surface area electrode when wetted with said fluid.

[c35]   35. The system of claim 34, said lower high surface area electrode comprising a thickness matching said thickness of said upper high surface area electrode by approximately ± 10%.

[c36]   36. The system of claim 1, said ionic preconcentration cell further comprising background data associated therewith:
said background data comprising data related to a rate at which photons are detected to be emitted from at least one background data energy channel of said preconcentration cell when said preconcentration cell is filled with a highly purified form of a fluid of interest and exposed to x-rays.

[c37]   37. The system of claim 1, said ionic preconcentration cell further comprising sensitivity data associated therewith:
said sensitivity data comprising data related to a rate at which photons are detected to be emitted from at least one sensitivity data energy channel of said preconcentration cell when said preconcentration cell is filled with a first calibration solution containing at least one element of interest in said fluid of interest in known concentration above a minimum detection level of x-ray detection equipment to be used for said detecting and measuring, and exposed to x-rays.

[c38]   38. The system of claim 2, said ionic preconcentration cell further comprising ion extraction rate data acquired from and associated therewith:
said ion extraction rate data comprising data related to a rate at which photons are detected to be emitted from said at least one ion extraction rate data energy channel of said preconcentration cell when a second calibration solution containing said at least one element of interest in said fluid of interest in known concentration below said minimum detection level of x-ray detection equipment

to be used for said detecting and measuring is flowed through said central flow interelectrode gap at a substantially constant flow rate while said voltage application means applies said voltage differential across said electrodes below an electrochemical potential of said at least one element of interest and below an electrolysis potential of said second calibration solution, and is exposed to x-rays.

[c39]   39. The system of claim 2, said ionic preconcentration cell further comprising background data, sensitivity data, and ion extraction rate data acquired from and associated therewith:

said background data comprising data related to a rate at which photons are detected to be emitted from at least one background data energy channel of said preconcentration cell when said preconcentration cell is filled with a highly purified form of a fluid of interest and exposed to x-rays;

said sensitivity data comprising data related to a rate at which photons are detected to be emitted from at least one sensitivity data energy channel of said preconcentration cell when said preconcentration cell is filled with a first calibration solution containing at least one element of interest in said fluid of interest in known concentration above a minimum detection level of x-ray detection equipment to be used for said detecting and measuring, and exposed to x-rays; and

said ion extraction rate data comprising data related to a rate at which photons are detected to be emitted from said at least one ion extraction rate data energy channel of said preconcentration cell when a second calibration solution containing said at least one element of interest in said fluid of interest in known concentration below said minimum detection level of x-ray detection equipment to be used for said detecting and measuring is flowed through said central flow interelectrode gap at a substantially constant flow rate while said voltage application means applies said voltage differential across said electrodes below an electrochemical potential of said at least one element of interest and below an electrolysis potential of said second calibration solution, and is exposed to x-rays.

[c40]   40. The system of claim 2, further comprising:

test data accumulation means for obtaining test data comprising data related to a rate at which photons are detected to be emitted from said at least one energy channel of said preconcentration cell when said fluid, suspected to contain at least one element of interest, is flowed through said central flow interelectrode gap at a substantially constant flow rate while said voltage application means applies said voltage differential across said electrodes below an electrochemical potential of said at least one element of interest and below an electrolysis potential of said fluid, and is exposed to x-rays.

[c41]   41. The system of claim 40, further comprising:
analysis means for analyzing said test data and deducing therefrom a concentration in said fluid, if any, of the suspected at least one element of interest.

[c42]   42. The system of claim 39, further comprising:
test data accumulation means for obtaining test data comprising data related to a rate at which photons are detected to be emitted from said at least one energy channel of said preconcentration cell when said fluid, suspected to contain at least one element of interest, is flowed through said central flow interelectrode gap at a substantially constant flow rate while said voltage application means applies said voltage differential across said electrodes below an electrochemical potential of said at least one element of interest and below an electrolysis potential of said fluid, and is exposed to x-rays.

[c43]   43. The system of claim 42, further comprising:
analysis means for analyzing said test data in relation to said background data, said sensitivity data, and said ion extraction rate data, and deducing therefrom a concentration in said fluid, if any, of the suspected at least one element of interest.

[c44]   44. The system of claim 2, further comprising:
x-ray source means for exposing said preconcentration cell to x-rays while flowing said fluid and while applying said voltage differential.

[c45]
          45. The system of claim 2, further comprising:

a transportable voltage supply for continuing to apply said voltage differential: after ceasing flowing said fluid, while transporting said ionic preconcentration cell to an x-ray source means for emitting x-rays toward said preconcentration cell, and while exposing said preconcentration cell to x-rays.

[c46]   46. The system of claim 1, further comprising:
flow control means for controlling a flow rate of said fluid through said ionic preconcentration cell so as to maintain ϵ, which designates a predetermined percentage of at least one element of interest to be extracted from said fluid, below approximately 5% for said at least one element of interest.

[c47]   47. The system of claim 46, wherein said ϵ is maintained below an extraction percentage selected from the extraction percentage group consisting of approximately 4%, 3%, 2% and 1%.

[c48]

48. The system of claim 2, further comprising flow control means for:
controlling a flow rate F of said fluid through said ionic preconcentration cell and maintaining said F at a substantially constant level so as to maintain ϵ, which designates a predetermined percentage of at least one element of interest to be extracted from said fluid and is specified by:

$$\varepsilon = \frac{\Gamma_{i,e}}{\Gamma_{i,s}} = \frac{\sigma \Phi}{qd} \frac{w_i}{w_f} \frac{A}{n_f CF} \times 100\%$$

below approximately 5% for said at least one element of interest; wherein:
Γ_{ie} and Γ_{is} designate rates at which ions of said at least one element of interest are respectively extracted from said fluid by said cell and supplied to said cell by said fluid, σ designates a composite conductivity of said fluid, Φ designates a potential applied by said voltage application means across said electrodes, d designates said predetermined interelectrode gap width of said central flow interelectrode gap, $q = 1.60 \times 10^{-19}$ Coulomb designates the unit charge, A designates an ordinary surface area covered by said electrodes, n_f designates a number density of said fluid, w_i and w_f designate atomic / molecular weights, respectively, of said at least one element of interest and of said fluid, and C designates a concentration of said at least one element of interest in said fluid; and

for said concentration C in a range where conductivity varies substantially linearly with concentration, with C in units of parts per billion, σ is approximated by:

$$\sigma \approx 2 \times 10^{-9} C / \text{Ohm} - \text{cm}$$

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[c49]   49. The system of claim 48, wherein said ϵ is maintained below an extraction percentage selected from the extraction percentage group consisting of approximately 4%, 3%, 2% and 1%.

[c50]   50. The system of claim 2, said voltage application means applying said voltage differential across said electrodes below an electrochemical potential of at least one element of interest and below an electrolysis potential of said fluid.

[c51]   51. The system of claim 1, further comprising:
leakage current monitoring means for detecting a saturation state of said cell by monitoring a leakage current from said cell.

[c52]   52. The system of claim 51, further comprising:
ultra-low trace measuring means for measuring at least one element of interest comprising ultra-low trace, high valence ions in said fluid, based on said detecting said saturation state.

[c53]   53. The system of claim 1, further comprising:
leakage current monitoring means for estimating a concentration in said fluid of at least one element of interest by monitoring a leakage current in said cell; and time control means for controlling how long said fluid flows through said ionic preconcentration cell based on the estimate obtained by said leakage current monitoring means.

[c54]
The system of claim 1, further comprising: time control means for controlling how long said fluid flows through said ionic preconcentration cell based on setting an impurity concentration C, in a range where conductivity varies substantially linearly with concentration, to a predetermined desired concentration detection level and flowing said fluid for a time t given by:

$$t \propto \frac{S\ell}{\sigma} \propto \frac{S\ell}{C}$$

; wherein:

S designates a sensitivity of x-ray detection equipment to be used for said detecting and measuring;

λ designates a thickness of said upper high surface area electrode; and

σ designates a composite conductivity of said fluid.

[c55]   55. The system of claim 1, further comprising triggering means for triggering an action when said system detects that a concentration of at least one element of interest in said fluid has passed a predetermined threshold concentration.

[c56]   56. The system of claim 55, further comprising injection action means for injecting at least one element into said fluid as said action in response to said triggering means.

[c57]   57. The system of claim 55, further comprising dilution action means for diluting at least one diluting fluid into said fluid as said action in response to said triggering means.

[c58]   58. The system of claim 1, further comprising:
ionic release means for cleaning said preconcentration cell after use by releasing said ions accumulated within said high specific surface area of said electrodes after the accumulated ions have been exposed to x-rays and fluorescence from said preconcentration cell has been detected.

[c59]   59. The system of claim 1, further comprising:
x-ray source means for emitting x-rays toward said preconcentration cell; and
x-ray fluorescence detector means for detecting fluoresced energy emitted by said preconcentration cell due to said emitting said x-rays toward said preconcentration cell.

[c60]   60. The system of claim 59, further comprising:
analysis means for analyzing the detected fluoresced energy and deducing therefrom a concentration in said fluid of at least one element of interest in said fluid.

[c61]   61. The system of claim 1, further comprising:

telecommunications control means for controlling an operation of said ionic

preconcentration cell using a telecommunications link.

[c62]   62. A method for detecting and measuring concentrations of elements in fluids,

comprising the steps of:

flowing a fluid through a central flow interelectrode gap of an ionic

preconcentration cell separating an upper high specific surface area electrode

from a lower high specific surface area electrode of said ionic preconcentration

cell by a predetermined interelectrode gap width;

applying a voltage differential between said upper high surface area electrode

and said lower high surface area electrode while said fluid is flowing through

said central flow interelectrode gap; and

deducing a concentration of at least one element in said fluid, using data

associated with said cell.

[c63]   63. The method of claim 62, further comprising the step of:

supplying said voltage differential using a transportable voltage supply.

[c64].   64. The method of claim 62, further comprising the step of:

intimately contacting an upper surface of said upper high surface area electrode

with an upper transmission window of said ionic preconcentration cell.

[c65]   65. The method of claim 64, further comprising the step of:

intimately contacting a lower surface of said lower high surface area electrode

with a lower transmission window of said ionic preconcentration cell.

[c66]   66. The method of claim 62, further comprising the steps of:

entering a fluid into said ionic preconcentration cell using inlet flow means

therefor; and

enabling said fluid to flow through said central flow interelectrode gap.

[c67]   67. The method of claim 66, said step of entering said fluid further comprising

entering said fluid through said inlet flow means comprising at least one inlet

flow slot.

[c68]   68. The method of claim 66, said step of entering said fluid further comprising entering said fluid through said inlet flow means comprising a plurality of inlet flow tubes.

[c69]   69. The method of claim 66, further comprising the step of enhancing a turbulence of the flow of said fluid while entering said fluid.

[c70]   70. The method of claim 66, further comprising the step of cleaning debris from said inlet flow means using debris cleaning means therefor.

[c71]   71. The method of claim 62, further comprising the step of:
exiting said fluid out from said ionic preconcentration cell after said fluid has flowed through said central flow interelectrode gap using outlet flow means therefor.

[c72]   72. The method of claim 71, said step of exiting said fluid further comprising exiting said fluid through said outlet flow means comprising at least one outlet flow slot.

[c73]   73. The method of claim 71, said step of exiting said fluid further comprising exiting said fluid through said outlet flow means comprising a plurality of outlet flow tubes.

[c74]   74. The method of claim 71, further comprising the step of cleaning debris from said outlet flow means using debris cleaning means therefor.

[c75]   75. The method of claim 62, further comprising the step of:
embodying a body of said ionic preconcentration cell in a material comprising:
substantially no conductivity;
resistance to ionic leaching; and
resistance to radiation degradation from x-rays to which said preconcentration cell is to be exposed.

[c76]   76. The method of claim 62, further comprising the step of:
embodying a body of said ionic preconcentration cell in a material selected from the material group consisting of: plastic, glass, and fiberglass.

[c77] 77. The method of claim 62, further comprising the step of:

embodying a body of said ionic preconcentration cell in a material comprising

Delrin ® plastic.

[c78] 78. The method of claim 62, further comprising the step of:

providing said upper high surface area electrode with an upper electrode

thickness thereof less than or equal to approximately $\lambda = 1 / \mu * \rho$, wherein:

λ is an optical depth in said fluid of a characteristic photonic energy from an

element of interest for which a fluidic concentration is to be measured by said

method;

μ is a mass absorption coefficient of said upper high surface area electrode; and

ρ is a material density of said upper high surface area electrode.

[c79] 79. The method of claim 78, further comprising the step of:

providing said lower high surface area electrode with a lower electrode

thickness thereof less than or equal to approximately $\lambda = 1 / \mu * \rho$, wherein:

λ is an optical depth in said fluid of a characteristic photonic energy from an

element of interest for which a fluidic concentration is to be measured by said

method;

μ is a mass absorption coefficient of said lower high surface area electrode; and

ρ is a material density of said lower high surface area electrode.

[c80] 80. The method of claim 62, further comprising the step of:

providing ordinary surface areas of said upper high surface area electrode and

said lower high surface area electrode approximately equal to an interrogation

spot area of x-rays to which said preconcentration cell is to be exposed.

[c81] 81. The method of claim 64, further comprising the step of:

providing a surface area of said upper transmission window

approximately equal to an interrogation spot area of x-rays to which said

preconcentration cell is to be exposed.

[c82]
82. The method of claim 62, further comprising the step of:

providing said central flow interelectrode gap comprising said predetermined

interelectrode gap width, designated d, within a interelectrode gap range

specified by:

$$d = \frac{\sigma \, \Phi}{q \varepsilon} \frac{w_i}{w_f} \frac{A}{n_f \, C \, F} \times 100\% \approx 2 \times 10^{-9} \frac{\Phi w_i A}{q \varepsilon w_f n_f F} \times 100\% \propto \frac{\Phi A}{\varepsilon F}$$

; wherein:

ϵ designates a predetermined percentage of at least one element of interest to be extracted from said fluid, σ designates a composite conductivity of said fluid, Φ designates said voltage differential applied across said electrodes, $q = 1.60 \times 10^{-19}$ Coulomb designates the unit charge, A designates an ordinary surface area covered by said electrodes, n_f designates a number density of said fluid, w_i and w_f designate atomic / molecular weights, respectively, of at least one element of interest and of said fluid, C designates a concentration of said at least one element of interest in said fluid, and F designates a flow rate of said fluid through said ionic preconcentration cell;

said high surface area electrodes further comprise said ordinary surface area A approximately equal to an interrogation spot area of x-rays to which said preconcentration cell is to be exposed;

said ϵ is chosen to be below approximately 5% for said at least one element of interest;

said Φ is chosen to be below an electrochemical potential of said at least one element of interest and below an electrolysis potential of said fluid;

said F is chosen to exert no more than approximately .1 atm of pressure upon an upper transmission window of said ionic preconcentration cell in intimate contact with an upper surface of said upper high surface area electrode;

said n_f and said w_f are chosen with reference to said at least one element of interest; and

said w_i is chosen with reference to said fluid.

[c83]   83. The method of claim 62, further comprising the step of:

providing said central flow interelectrode gap comprising said predetermined interelectrode gap width, designated d, with:

a minimum gap width selected from the minimum gap width group consisting of 2 mm, 1 mm, .5 mm, and .25 mm; and

a maximum gap width selected from the maximum gap width group consisting of 2 mm, 5 mm and 10 mm.

[c84]   84. The method of claim 64, further comprising the step of providing said

upper transmission window comprising:

an atomic number below 10;

structural rigidity to support up to 1/10 atm. of pressure without bowing more

than approximately 100 microns;

substantial impermeability relative to said fluid;

x-ray transparency greater than 90% for characteristic photon energies from an

element of interest for which a fluidic concentration is to be measured by said

method;

x-ray scattering therefrom minimized to less than approximately 10% of

radiation scattered from a column of said fluid equal to one optical depth in

said fluid of a characteristic photonic energy from an element of interest for

which a fluidic concentration is to be measured by said method; and

freedom from any single contaminant in excess of 1 part per million, when

measured by x-ray fluorescence.

[c85]   85. The method of claim 65, further comprising the step of providing said lower

transmission window comprising:

an atomic number below 10;

structural rigidity to support up to 1/10 atm. of pressure without bowing more

than approximately 100 microns;

substantial impermeability relative to said fluid;

x-ray transparency greater than 90% for characteristic photon energies from an

element of interest for which a fluidic concentration is to be measured by said

method;

x-ray scattering therefrom minimized to less than approximately 10% of

radiation scattered from a column of said fluid equal to one optical depth in

said fluid of a characteristic photonic energy from an element of interest for

which a fluidic concentration is to be measured by said method; and

freedom from any single contaminant in excess of 1 part per million, when

measured by x-ray fluorescence.

[c86]   86. The method of claim 64, further comprising the step of:

providing said upper transmission window comprising Kapton ® .

[c87] 87. The method of claim 65, further comprising the step of:

providing said lower transmission window comprising Kapton ® .

[c88] 88. The method of claim 62 further comprising the step of:

providing said upper high surface area electrode and said lower high surface

area electrode comprising a high surface area material in turn comprising:

a large plurality of pores characterized by a specific surface area of at least

approximately 100 m ^{3} /g;

an average pore diameter of said pores between approximately 30 nm and 10

nm per pore;

a distribution of said pore diameters grouped with a standard deviation of less

than approximately 10nm around said average pore diameter;

an x-ray transparency greater than approximately 90% for characteristic photon

energies from an element of interest for which a fluidic concentration is to be

measured by said method;

electrical conductivity of 10-40 mOhms-cm when fabricated into a ¼ mm thick

electrode;

the ability to contain approximately at least 0.1% by weight of foreign material

relative to said high surface area material prior to saturation;

high structural rigidity wherein a displacement under the flow of said fluid does

not exceed approximately 0.25mm;

high wetting ability wherein an approximately ¼ mm thick sheet of said high

surface area material becomes substantially wetted in less than approximately

three seconds; and

freedom from metallic impurities in excess of approximately .5 parts per

million, when measured by XRF analysis.

[c89] 89. The method of claim 88, said large plurality of pores characterized by a

specific surface area of at least approximately 400 m ^{3} /g.

[c90] 90. The method of claim 88, said large plurality of pores characterized by a

specific surface area of at most approximately 1000 m ^{3} /g.

[c91] 91. The method of claim 89, said large plurality of pores characterized by a

specific surface area of at most approximately 1000 m ^{3} /g.

[c92]   92. The method of claim 62, further comprising the step of:

providing said upper high surface area electrode and said lower high surface area electrode each comprising nano-cellular carbon.

[c93]   93. The method of claim 62, further comprising the step of:

providing said upper high surface area electrode and said lower high surface area electrode each comprising a carbon aerogel.

[c94]   94. The method of claim 62, further comprising the step of:

providing said upper high surface area electrode with a thickness less than approximately $\lambda = 1 / \mu \rho$; wherein:

λ designates an optical depth of said upper high surface area electrode when wetted with said fluid;

μ designates a mass absorption coefficient of said high surface area electrode when wetted with said fluid; and

ρ designates a density of said high surface area electrode when wetted with said fluid.

[c95]   95. The method of claim 94, further comprising the step of:

providing said lower high surface area electrode with a thickness matching said thickness of said upper high surface area electrode by approximately $\pm$ 10%.

[c96]   96. The method of claim 62, further comprising the step of acquiring background data from said ionic preconcentration cell and associating said data therewith:

said step of acquiring said background data comprising the steps of:

filling said preconcentration cell with a highly purified form of a fluid of interest;

exposing the filled said preconcentration cell to x-rays; and

acquiring said background data related to a rate at which photons are detected to be emitted from at least one background data energy channel of said preconcentration cell.

[c97]

97. The method of claim 62, further comprising the step of acquiring sensitivity data from said ionic preconcentration cell and associating said data therewith:

said step of acquiring said sensitivity data comprising the steps of:

filling said preconcentration cell with a first calibration solution containing at least one element of interest in said fluid of interest in known concentration above a minimum detection level of x-ray detection equipment to be used for said detecting and measuring;

exposing the filled said preconcentration cell to x-rays; and

acquiring said sensitivity data related to a rate at which photons are detected to be emitted from at least one sensitivity data energy channel of said preconcentration cell.

[c98]   98. The method of claim 62, further comprising the step of acquiring ion extraction rate data from said ionic preconcentration cell and associating said data therewith:

said step of acquiring said ion extraction rate data comprising the steps of:

applying said voltage differential across said electrodes below an electrochemical potential of said at least one element of interest and below an electrolysis potential of said second calibration solution;

flowing a second calibration solution containing said at least one element of interest in said fluid of interest in known concentration below said minimum detection level of x-ray detection equipment to be used for said detecting and measuring through said central flow interelectrode gap at a substantially constant flow rate;

exposing said preconcentration cell with said second calibration solution therein to x-rays; and

acquiring said ion extraction rate data related to a rate at which photons are detected to be emitted from said at least one ion extraction rate data energy channel of said preconcentration cell.

[c99]   99. The method of claim 62, further comprising the steps of acquiring background data, sensitivity data, and ion extraction rate data from said ionic preconcentration cell and associating said data therewith:

said step of acquiring said background data comprising the steps of:

filling said preconcentration cell with a highly purified form of a fluid of interest;

exposing the filled said preconcentration cell to x-rays; and

acquiring said background data related to a rate at which photons are detected to be emitted from at least one background data energy channel of said preconcentration cell;

said step of acquiring said sensitivity data comprising the steps of:

filling said preconcentration cell with a first calibration solution containing at least one element of interest in said fluid of interest in known concentration above a minimum detection level of x-ray detection equipment to be used for said detecting and measuring;

exposing the filled said preconcentration cell to x-rays; and

acquiring said sensitivity data related to a rate at which photons are detected to be emitted from at least one sensitivity data energy channel of said preconcentration cell; and

said step of acquiring said ion extraction rate data comprising the steps of:

applying said voltage differential across said electrodes below an electrochemical potential of said at least one element of interest and below an electrolysis potential of said second calibration solution;

flowing a second calibration solution containing said at least one element of interest in said fluid of interest in known concentration below said minimum detection level of x-ray detection equipment to be used for said detecting and measuring through said central flow interelectrode gap at a substantially constant flow rate;

exposing said preconcentration cell with said second calibration solution therein to x-rays; and

acquiring said ion extraction rate data related to a rate at which photons are detected to be emitted from said at least one ion extraction rate data energy channel of said preconcentration cell.

[c100]

100. The method of claim 62, further comprising the steps of:

applying said voltage differential across said electrodes below an electrochemical potential of said at least one element of interest and below an electrolysis potential of said fluid, suspected to contain at least one element of interest;

flowing said fluid through said central flow interelectrode gap at a substantially constant flow rate;

exposing said preconcentration cell with said fluid therein to x-rays; and

acquiring test data related to a rate at which photons are detected to be emitted from at least one test data energy channel of said preconcentration cell.

[c101]   101. The method of claim 100, further comprising the step of:

analyzing said test data and deducing therefrom a concentration in said fluid, if any, of the suspected at least one element of interest.

[c102]   102. The method of claim 99, further comprising the steps of:

applying said voltage differential across said electrodes below an electrochemical potential of said at least one element of interest and below an electrolysis potential of said fluid, suspected to contain at least one element of interest;

flowing said fluid through said central flow interelectrode gap at a substantially constant flow rate

exposing said preconcentration cell with said fluid therein to x-rays; and

acquiring test data related to a rate at which photons are detected to be emitted from at least one test data energy channel of said preconcentration cell.

[c103]   103. The method of claim 102, further comprising the step of:

analyzing said test data in relation to said background data, said sensitivity data, and said ion extraction rate data, and deducing therefrom a concentration in said fluid, if any, of the suspected at least one element of interest.

[c104]   104. The method of claim 62, further comprising the steps of:

exposing said preconcentration cell to x-rays while flowing said fluid and while applying said voltage differential.

[c105]

105. The method of claim 62, further comprising the steps of:

ceasing flowing said fluid while continuing to apply said voltage differential;

transporting said ionic preconcentration cell to an x-ray source means for emitting x-rays toward said preconcentration cell while continuing to apply said voltage differential; and

exposing said preconcentration cell to x-rays from said x-ray source means while continuing to apply said voltage differential.

[c106]   106. The method of claim 62, further comprising the step of:

controlling a flow rate of said fluid through said ionic preconcentration cell so a to maintain ϵ, which designates a predetermined percentage of at least one element of interest to be extracted from said fluid, below approximately 5% for said at least one element of interest.

[c107]   107. The method of claim 106, further comprising the step of:

maintaining said ϵ below an extraction percentage selected from the extraction percentage group consisting of approximately 4%, 3%, 2% and 1%.

[c108]

108. The method of claim 62, further comprising the step of:

controlling a flow rate F of said fluid through said ionic preconcentration cell and maintaining said F at a substantially constant level so as to maintain ϵ, which designates a predetermined percentage of at least one element of interest to be extracted from said fluid and is specified by:

$$\epsilon = \frac{\Gamma_{ie}}{\Gamma_{is}} = \frac{\sigma\,\Phi}{q\,d}\frac{w_i}{w_f}\frac{A}{n_f\,C\,F}\times 100\%$$

,

below approximately 5% for said at least one element of interest; wherein:
Γ_{ie} and Γ_{is} designate rates at which ions of said at least one element of interest are respectively extracted from said fluid by said cell and supplied to said cell by said fluid, σ designates a composite conductivity of said fluid, Φ designates said voltage differential applied across said electrodes, d designates said predetermined interelectrode gap width of said central flow interelectrode gap, $q = 1.60\times 10^{-19}$ Coulomb designates the unit charge, A designates an ordinary surface area covered by said electrodes, n_f designates a number density of said fluid, w_i and w_f designate atomic / molecular weights, respectively, of said at least one element of interest and of said fluid, and C designates a concentration of said at least one element of interest in said fluid; and

for said concentration C in a range where conductivity varies substantially

linearly with concentration, with C in units of parts per billion, σ is approximated by:

$$\sigma \approx 2 \times 10^{-9}\, C\, /\, \text{Ohm} - \text{cm}$$

.

[c109]   109. The method of claim 108, further comprising the step of: maintaining said ϵ below an extraction percentage selected from the extraction percentage group consisting of approximately 4%, 3%, 2% and 1%.

[c110]   110. The method of claim 62, further comprising the step of: applying said voltage differential across said electrodes below an electrochemical potential of at least one element of interest and below an electrolysis potential of said fluid.

[c111]   111. The method of claim 62, further comprising the step of: detecting a saturation state of said cell by monitoring a leakage current from said cell.

[c112]   112. The method of claim 111, further comprising the step of: measuring at least one element of interest comprising ultra-low trace, high valence ions in said fluid, based on said detecting said saturation state.

[c113]   113. The method of claim 62, further comprising the steps of: estimating a concentration in said fluid of at least one element of interest by monitoring a leakage current in said cell; and controlling how long said fluid flows through said ionic preconcentration cell based on the estimate obtained by said leakage current monitoring means.

[c114]

114. The method of claim 1, further comprising the steps of: setting an impurity concentration C, in a range where conductivity varies substantially linearly with concentration, to a predetermined desired concentration detection level; and controlling how long said fluid flows through said ionic preconcentration cell by flowing said fluid for a time t given by:

$$t \propto \frac{S\ell}{\sigma} \propto \frac{S\ell}{C}$$

; wherein:

S designates a sensitivity of x-ray detection equipment to be used for said detecting and measuring;

λ designates a thickness of said upper high surface area electrode; and

σ designates a composite conductivity of said fluid.

[c115]   115. The method of claim 62, further comprising the step of:
triggering an action when said method detects that a concentration of at least one element of interest in said fluid has passed a predetermined threshold concentration.

[c116]   116. The method of claim 115, further comprising the steps of:
injecting at least one element into said fluid as said action in response to said triggering.

[c117]   117. The method of claim 115, further comprising the steps of:
diluting at least one diluting fluid into said fluid as said action in response to said triggering.

[c118]   118. The method of claim 62, further comprising the step of:
cleaning said preconcentration cell after use by releasing said ions accumulated within said high specific surface area of said electrodes after the accumulated ions have been exposed to x-rays and fluorescence from said preconcentration cell has been detected.

[c119]   119. The method of claim 62, further comprising the steps of:
emitting x-rays toward said preconcentration cell; and
detecting fluoresced energy emitted by said preconcentration cell due to said emitting said x-rays toward said preconcentration cell.

[c120]   120. The method of claim 119, further comprising the step of:
analyzing the detected fluoresced energy and deducing therefrom a concentration in said fluid of at least one element of interest in said fluid.

[c121]
121. The method of claim 62, further comprising the step of:
controlling an operation of said ionic preconcentration cell using a

telecommunications link.